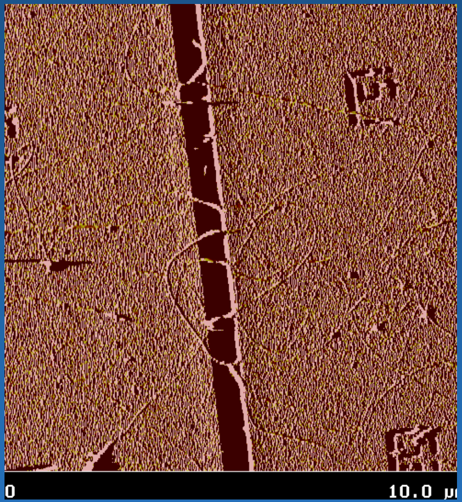
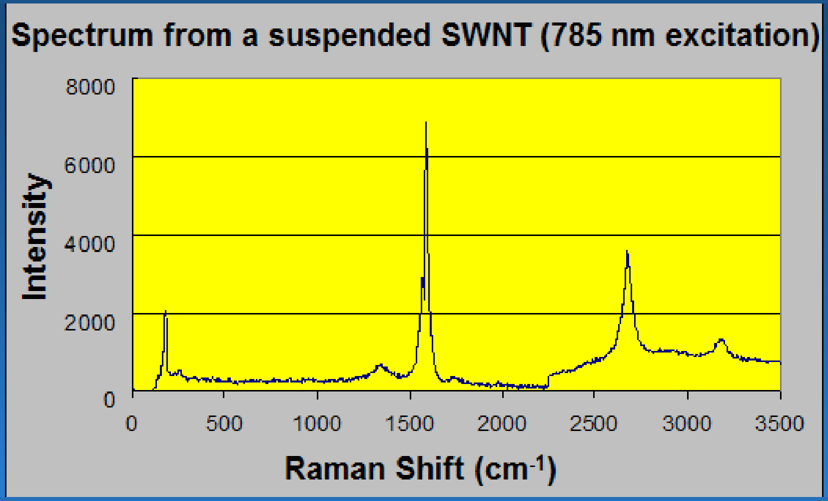
Characterization of Individual Single-Walled Carbon Nanotubes by Resonance Raman Spectroscopy and Fluorescence

Prof. Michael Tinkham, Harvard University, DMR-0244441



Nanotubes are suspended to enhance Raman and fluorescence signals.



Semiconducting nanotube, diameter ≈ 1.3 nm

A single-walled carbon nanotube (SWNT) can be imagined as a hexagonal graphite sheet rolled into a hollow tube of nanometer scale diameter. These have shown potential for future electronic devices. Our research focuses on characterizing the electronic structure of individual SWNTs. To isolate an individual nanotube for analysis, we have developed a multi-step fabrication process yielding SWNTs suspended over trenches. The figure in the upper left corner is an atomic force microscope image showing the suspended SWNTs. We utilize a laser to optically excite a nanotube whose electronic transition is in resonance with the laser energy, and the emitted light is then collected by detectors. From the Raman shift between exciting and emitted frequencies, we can determine the nanotube's diameter and its intrinsic electronic structure (metallic or semiconducting). The figure in the upper right corner shows Raman shifts for one particular suspended nanotube. Fluorescence spectroscopy on the same nanotube should elucidate its exact electronic transition energies.

Single-Walled Carbon Nanotubes

It has long been known that the chemical element Carbon can crystallize as Diamond, a very hard material, or as Graphite, which consists of loosely bound layers of carbon atoms arranged in a hexagonal pattern. More recently it has been discovered that carbon can also form *nanotubes*, formed by “rolling up” a graphite sheet to form a tube only a few nanometers in diameter. Since this roll-up can occur in many directions and with many diameters, carbon nanotubes actually form a huge variety of “species”, some metallic, some insulating, and some semiconducting, each with its own detailed electronic structure. This diversity has lead to many possibilities for electronic device applications, but the diversity also complicates the process of fabricating a desired version.

Studies of the optical spectra provide a powerful “contactless” probe of the electronic and vibrational excitations characteristic of the various types of tubes. We expect our combination of two different types of optical measurements (Raman and Photoluminescence) on a *single* nanotube (as opposed to a sample containing a mixture of many types) will allow us to resolve the reason for certain discrepancies in earlier measurements, and bring practical applications of these remarkable materials nearer to fruition.

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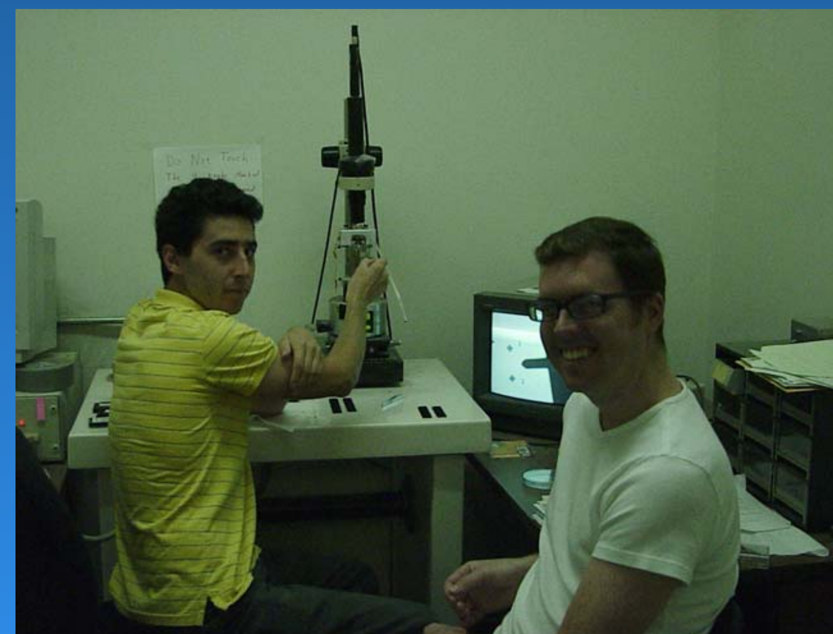
Education and Outreach

This project was initiated by postdoc Steve Cronin, in collaboration with a group at Boston University. During this past summer, he has been assisted by Alexander (Sasha) Stolyarov, a rising senior physics major at The University of Texas at Dallas. As an REU student at Harvard University, Sasha worked closely with his mentor, Dr. Cronin, on all aspects of this project. Impressed by the flow of research in this setting, Sasha has decided he wants to pursue experimental nanoscale physics as a graduate student.

Dr. Cronin and Sasha preparing to evaporate 0.7nm of Iron on a substrate in preparation for nanotube growth.



Sasha about to place a sample on the atomic force microscope stage.